Study: Future astronauts could use their own urine to help build moon bases

Enlarge / Future moon bases could be built with 3D printers that mix materials such as Moon regolith, water, and astronauts' urine.

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Early last year, NASA announced an ambitious plan to return American astronauts to the Moon and establish a permanent base there, with an eye toward eventually placing astronauts on Mars. The Artemis Moon Program has its share of critics, including many in the US House of Representatives, who appear to prefer a stronger focus on a crewed mission to Mars. As Ars' Eric Berger reported last August, "NASA stands a very real risk of turning the Artemis Program into a repeat of the Apollo Program—a flags-and-footprints sprint back to the Moon with no follow-through in the form of a lunar base or a sustained presence in deep space."

But if the Artemis Program's ambitious objectives survive the appropriations process, materials science will be crucial to its success, particularly when it comes to the materials needed to construct a viable lunar base. Concrete, for instance, requires a substantial amount of added water in order to be usable *in situ*, and there is a pronounced short supply of water on the moon. In a new paper in the Journal of

Cleaner Production, an international team of scientists suggests that astronauts setting up a base on the moon could use the urea in their urine as a plasticizer to create a concrete-like building material out of lunar soil.

There’s certainly a strong argument to be made for using existing materials on the Moon itself to construct a lunar base. NASA estimates that it costs around $10,000 to transport one pound of material into orbit, according to the authors. Past proposals have called for 3D printing with Sorel cement, which requires significant amounts of chemicals and water (consumables), and a rocklike material that would require both water and phosphoric acid as a liquid binder. (The latter might be better suited to constructing a base on Mars.)

Spiking lunar regolith (the fine powdery soil on the surface of the Moon) with geopolymers could provide a solution. Geopolymers bring several advantages to the concrete mix: they are resistant to fire and have low thermal conductivity, provide radiation shielding, and can withstand the elements of the harsh lunar environment (high amounts of sulfates, for example, as well as attacks from acid and salt). They typically show good freeze/thaw resistance and high compressive strength, too.

- Device for printing 3D samples.
  Shima Pilehvar et al./ Journal of Cleaner Production
- Tests to see the ability to form layers of a mixture of material with 3% urea (sample U) and another with 3% naphthalene, a common plasticizer (sample N).
  Shima Pilehvar et al./ Journal of Cleaner Production

3D printing is favored for lunar construction to minimize risks to humans on the Moon during construction, but that layer-by-layer manufacturing approach requires a material that is pliable enough for extrusion, among other desirable properties. On Earth, one could just add extra water, but this

is not feasible on the Moon. There are so-called super-plasticizers that would be ideal for this purpose, but there are no naturally occurring super-plasticizers on the Moon either, so this, too, would require expensive transport. (Plasticizers are chemical additives that serve to soften initial concrete mixtures so that they are pliable enough to pour or shape before hardening.)

But there will be human astronauts on the Moon during construction, producing organic waste (urine and feces). And the urea component in urine might serve as an effective super-plasticizer for 3D printing building materials for lunar bases. Scientists from Norway, Spain, the Netherlands, and Italy set out to establish proof of principle with the European Space Agency's blessing. (Along with its Chinese counterpart, the ESA is also interested in establishing a lunar base.)

> *"The idea is to use what is there: regolith—loose material from the Moon's surface—and the water from the ice present in some areas."*

"To make the geopolymer concrete that will be used on the Moon, the idea is to use what is there: regolith—loose material from the Moon's surface—and the water from the ice present in some areas," said co-author Ramón Pamies of the Polytechnic University of Cartagena (Murcia). "With this study we have seen that a waste product, such as the urine of the personnel who occupy the Moon bases, could also be used. The two main components of this body fluid are water and urea, a molecule that allows the hydrogen bonds to be broken and therefore reduces the viscosities of many aqueous mixtures."

The team used a synthetic material designed by the ESA with similar characteristics as lunar regolith, adding urea, a polycarboxylate-based super-plasticizer, and a naphthalene-based super-plasticizer to different batches, as well as making a control batch without any super-plasticizer. Then the

researchers used a 3D printer to make mud cylinders out of each batch. They tested each batch for the ability to support heavy weights while maintaining shape, including after each of eight freeze/thaw cycles, mimicking as much as possible the harsh lunar conditions.

The results: the batches with no super-plasticizer and the polycarboxylate-based super-plasticizer proved too stiff for 3D printing and were prone to cracking. The batches with urea- and naphthalene-based super-plasticizers, in contrast, proved malleable enough for extrusion with little (naphthalene) to no (urea) fractures, and they also retained their shape under heavy external loads. Both those batches showed a decrease in compressive strength and some microcracks after eight freeze/thaw cycles, however. Nonetheless, "Overall, urea exhibits promising properties as a super-plasticizer for 3D printing of lunar geopolymers," the authors concluded.

More to do

This is primarily a proof of principle, and more experiments are needed. The materials were not subjected to a vacuum, for instance, which could cause crack formation due to the evaporation of volatile components. The team also has not yet evaluated how well lunar regolith geopolymers would hold up under meteorite bombardment or how well they would shield humans from high radiation levels.

There's also one other pragmatic concern. "We have not yet investigated how the urea would be extracted from the urine, as we are assessing whether this would really be necessary, because perhaps [urine's] other components could also be used to form the geopolymer concrete," co-author Anna-Lena Kjøniksen said. "The actual water in the urine could be used for the mixture, together with that which can be obtained on the Moon, or a combination of both."

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